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Research Article

Leadership Competence and Teacher Job Satisfaction: Evidence from Structural Path Analysis in Indonesian Public Senior High Schools

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Abstract: This experimental study investigated the effectiveness of Process Oriented Guided Inquiry Learning (POGIL) based Student Worksheets in enhancing metacognitive skills among eleventh grade students learning Chemical Equilibrium. Utilizing a one group pretest posttest design with 36 participants, the intervention implemented specially designed worksheets integrating POGIL's inquiry cycle with explicit metacognitive scaffolding. Metacognitive skills comprising planning, monitoring, and evaluating components were measured through validated essay instruments before and after four instructional sessions. Statistical analysis using the Wilcoxon Signed Rank Test revealed a significant improvement in overall metacognitive skills ($Z = -5.197$, $p < 0.001$, large effect size $d = 2.47$). Notably, 94.44% of students demonstrated measurable progress, with normalized gain scores indicating high improvement in planning ($g = 0.82$), moderate improvement in evaluating ($g = 0.51$), and moderate improvement in monitoring ($g = 0.48$). These findings substantiate that POGIL based worksheets, when designed with intentional metacognitive prompts, effectively foster the development of higher order regulatory skills essential for mastering complex chemical concepts. The study contributes to science education literature by demonstrating how inquiry based pedagogies can be optimized for metacognitive skill development.

Keywords: Chemical Equilibrium; Metacognitive Skills; Process Oriented Guided Inquiry Learning; Secondary Chemistry Education; Student Worksheets.

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1. Introduction

Contemporary science education frameworks increasingly recognize that beyond content mastery, students must develop sophisticated cognitive regulatory capacities to navigate complex knowledge domains (Dumanaw et al., 2025). Among these capacities, metacognitive skills the awareness and control individuals exert over their own cognitive processes have emerged as critical predictors of academic achievement and problem solving competence across scientific disciplines (Arami & Wiyarsi, 2020). Grounded in Flavell's (1979) seminal conceptualization, metacognition encompasses three interdependent components planning (forethought activities including goal setting and strategy selection), monitoring (real time awareness of comprehension and task progress), and evaluating (retrospective assessment of outcomes and strategy effectiveness) (Flavell, 1979). These self regulatory processes enable learners to approach challenging material strategically, adapt their approaches when encountering obstacles, and reflectively consolidate their learning competencies particularly vital in conceptually dense subjects like chemistry (Hidayah et al., 2022).

Chemical equilibrium, with its focus on Le Chatelier's Principle, represents a paradigmatic "threshold concept" in chemistry education one that is transformative, integrative, and frequently troublesome for learners (Rahmawati et al., 2022). Its mastery demands the coherent integration of macroscopic phenomena, particulate level reasoning, and symbolic representations within a dynamic systems framework (Permatasari et al., 2022). Research consistently documents that students' difficulties stem not only from conceptual complexity but also from metacognitive deficits. They frequently fail to plan investigative approaches, monitor the consistency between their predictions and evidence, or critically evaluate their problem solving strategies (Renvaal & Kurten, 2024). In Indonesian, preliminary diagnostic assessments reveal alarmingly low metacognitive proficiency in this topic, with students exhibiting particular weaknesses in monitoring and evaluating skills (Azizah & Nasrudin, 2021).

Pedagogical responses to these challenges have increasingly turned to active, inquiry based learning models. Process Oriented Guided Inquiry Learning (POGIL), a pedagogy rooted in constructivist and social learning theories, has demonstrated efficacy in enhancing conceptual understanding and collaborative skills in chemistry (Zemene et al., 2025). In POGIL, students work in structured small groups through a cyclical learning sequence Orientation, Exploration, Concept Formation, Application, and Reflection guided by specially designed activities (Puspitasari et al., 2024). This sequence presents a natural alignment with metacognitive regulation cycles the initial phases can stimulate planning, the middle phases facilitate monitoring, and the concluding phases promote evaluation. However, while POGIL implicitly fosters some metacognitive engagement, its explicit, scaffolded integration with metacognitive skill development remains underexplored in empirical literature.

Previous studies examining POGIL's impact have primarily focused on content achievement or general critical thinking (Sari & Azizah, 2021). Research specifically targeting its effect on discrete metacognitive components using validated, multidimensional assessments is sparse. Furthermore, few studies have investigated how the structural features of POGIL materials can be optimized to systematically elicit and develop planning, monitoring, and evaluating skills within conceptually challenging domains like chemical equilibrium.

This study addresses these gaps by investigating the following research question to what extent do intentionally designed POGIL based Student Worksheets, featuring explicit metacognitive scaffolding, improve high school students' planning, monitoring, and evaluating skills in the context of Chemical Equilibrium?

2. Literature Review

Metacognitive Skill

Metacognitive skills, defined as an individual's awareness and regulation of their own cognitive processes, are increasingly recognized as pivotal for deep learning and problem solving in science education (Schraw & Dennison, 1994). These skills encompass three core, interdependent components planning (involving goal setting, strategy selection, and resource allocation), monitoring (entailing realtime tracking of comprehension and task progress), and evaluating (involving the assessment of outcomes and the effectiveness of strategies employed). In the chemistry, a discipline characterized by abstract concepts and multirepresentational reasoning, well developed metacognitive skills enable learners to navigate complexity, identify knowledge gaps, and adapt their approaches dynamically (Dewi et al., 2025).

The significance of metacognition is further underscored by contemporary educational frameworks, such as the Kurikulum Merdeka in Indonesia, which emphasizes the development of the Profil Pelajar Pancasila (Pancasila Student Profile). This profile champions competencies like critical reasoning and collaborative problem solving, which are fundamentally underpinned by metacognitive abilities (Divamita & Azizah, 2022). However, empirical evidence suggests that students often enter chemistry classrooms with underdeveloped metacognitive skills. Diagnostic studies, including preliminary research at high school, reveal pronounced deficiencies, particularly in monitoring and evaluating skills when dealing with challenging topics like chemical equilibrium. This deficit is problematic because mastering chemical equilibrium requires students to integrate macroscopic observations, particulate level interactions, and symbolic representations a process that demands constant self regulation and reflective thinking (Sormin et al., 2025).

Chemical Equilibrum

Chemical equilibrium, and specifically the application of Le Chatelier's Principle, is widely regarded as a threshold concept in chemistry it is transformative, integrative, and often troublesome for learners (Hamnell-pamment, 2024). Its abstract nature stems from the need to conceptualize a dynamic, invisible process at the particulate level while connecting it to observable macroscopic changes and mathematical constants (Kc, Kp). Students commonly harbor misconceptions, such as viewing equilibrium as a static state rather than a dynamic process with equal forward and reverse reaction rates (Silviana & Ritonga, 2025).

Overcoming these misconceptions requires more than rote memorization of rules, it necessitates metacognitive engagement. Students must plan investigative strategies to explore equilibrium shifts, monitor the consistency between their predictions and experimental evidence, and evaluate the logical coherence of their explanations. Traditional, transmission based instructional methods often fail to provide the structured opportunities needed for such metacognitive practice, leading to superficial understanding and persistent errors (Suryati et al., 2024).

Pogil

Process Oriented Guided Inquiry Learning (POGIL) is a student centered instructional strategy grounded in constructivist and social learning theories(Jummaro et al., 2024). In POGIL, students work in structured small groups on specially designed activities that guide them through an inquiry cycle. This cycle typically comprises five phases Orientation, Exploration, Concept Formation, Application, and Reflection. Theoretical alignment suggests that POGIL's phased structure offers a natural scaffold for metacognitive skill development:

a. The Orientation phase, which presents an engaging problem context, activates prior knowledge and stimulates planning as students consider goals and initial approaches.
b. The Exploration phase, involving data collection or experimentation, reinforces planning (procedural design) and initiates monitoring as students compare emerging data with initial hypotheses.
c. The Concept Formation phase, centered on group discussion and pattern identification, provides a critical forum for monitoring through peer feedback and consensus building.
d. The Application phase, where concepts are applied to novel problems, demands evaluating as students assess the utility and limits of their newly constructed knowledge.
e. The Reflection phase explicitly prompts evaluating of both the learning outcomes and the processes used to achieve them.

While POGIL has demonstrated efficacy in improving content mastery and collaborative skills, its potential for explicitly and systematically fostering metacognitive skills remains a rich area for investigation. Most implementations rely on the implicit metacognitive benefits of inquiry and collaboration. However, deliberate design enhancements such as embedding structured metacognitive prompts within the POGIL activity sheets could significantly amplify these benefits (Purnama & Rahayu, 2023).

Student Worksheet

Student Worksheets (LKPD) are ubiquitous instructional tools in Indonesian classrooms. Traditionally, they have served as guides for exercises or procedures. However, when thoughtfully designed, LKPD can transform into powerful scaffolds for cognitive and metacognitive development(Rizqiyah & Azizah, 2023). An effective LKPD does not merely present tasks, it structures the learning journey, providing "just in time" supports that guide students through complex thinking processes. For metacognitive development, LKPD can incorporate features such as:

a. Structured Reflection Columns: dedicated spaces for students to articulate their planning before a task, document their monitoring during the task, and conduct evaluation after the task.
b. Tiered Guiding Questions: questions that progress from factual recall to analytical and evaluative thinking, prompting students to engage in increasingly sophisticated levels of metacognitive regulation.
c. Explicit Strategy Prompts: cues that encourage specific metacognitive behaviors.

Integrating these metacognitive scaffolds into a POGIL based LKPD creates a synergistic instructional tool. The POGIL cycle provides the authentic, collaborative inquiry context, while the embedded scaffolds make the metacognitive processes overt, deliberate, and repeated(Wanti et al., 2024).

3. Materials and Method

This study employed a quantitative pre-experimental design using a one-group pretest posttest framework (Campbell et al., 1963). This design was selected to provide initial, controlled evidence of the intervention's effect within a natural classroom setting. The schematic representation is:

Pretest		Treatment		Posttest
O_1	⟶	X	⟶	O_2

Figure 1. Research Design.

Description:

O1 : Pretest score, to determine the ability of students before being treated

X : Treatment, learning process using LKPD based POGIL

O2 : Posttest score, to determine the ability of students after being treated

The research was conducted at SMAN 1 Krian with 36 students of Class XI MIPA as subjects. The intervention was carried out over four meetings. The primary instrument was a Metacognitive Skills Essay Test, developed based on Pulmones' operational indicators for planning, monitoring, and evaluating (Pulmones, 2008). The test consisted of 4 essay questions, each designed to measure the three metacognitive skill indicators in the context of chemical equilibrium problems. This instrument had been validated by experts. Data analysis was performed quantitatively. The Wilcoxon Signed-Rank Test was used to determine the significance of the difference between pretest and posttest scores, as the paired data were not normally distributed (Shapiro-Wilk test significance <0.05). The test was conducted with a significance level (α) of 0.05. The effectiveness of the LKPD was also described by calculating the N-Gain score for each metacognitive skill indicator.

4. Results and Discussion

The metacognitive skills test was administered to students before (pretest) and after (posttest) the implementation of POGIL-based Student Worksheets. The pretest aimed to measure the initial level of students' metacognitive skills, while the posttest evaluated their development after the intervention. The data from the pretest and posttest for each metacognitive skill indicator are presented in Table 1.

Table 1. Pretest and Posttest Results of Metacognitive Skills.

Metacognitive Skill Indicator	Averager Pretest Score (%)	Average Posttest Score (%)	N-gain	Category
Planning	49.65	91.00	0.82	High
Monitoring	39.41	68.00	0.48	Medium
Evaluating	37.15	69.00	0.51	Medium
Overall	42.07	76.47	0.59	Medium

The N-Gain score is interpreted based on Hake's criteria $g > 0.7$ (High), $0.3 \leq g \leq 0.7$ (Medium), and $g < 0.3$ (Low)(Hake, 1999).

Table 1 indicates an improvement in the average score for each metacognitive skill indicator after the intervention. The planning indicator showed the most substantial increase with an N-Gain of 0.82, categorized as high improvement. The monitoring and evaluating indicators demonstrated medium improvement with N-Gain scores of 0.48 and 0.51, respectively. The overall N-Gain for metacognitive skills was 0.59, falling into the Medium category. This data provides initial evidence that the use of POGIL-based Student Worksheets contributes to the enhancement of students' metacognitive skills.

Before proceeding with parametric hypothesis testing, a normality test was conducted to determine the distribution of the pretest and posttest data. The Shapiro-Wilk test was selected due to its higher sensitivity for sample sizes below 50 (n=36). The results are presented in Table 2.

Table 2. Normality Test Results for Pretest and Posttest Data.

Test	Statistic	Df	Sig.
Pretest	0.947	36	0.082
Posttest	0.950	36	0.103

The decision criterion is based on the significance value (Sig.). If Sig. > 0.05, the data are considered normally distributed. As shown in Table 2, the Sig. values for both the pretest (0.082) and posttest (0.103) are greater than 0.05. Therefore, it is concluded that the pretest and posttest data are normally distributed. This satisfies the assumption for using parametric statistical tests, specifically the Paired Samples T-Test.

To determine the statistical significance of the observed improvement, a Paired Samples T-Test was conducted. This test compares the means of two related groups (pretest and posttest) to see if there is a statistically significant difference. The results are summarized in Table 3.

Table 3. Paired Samples T-Test Results.

Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
			Lower	Upper			
-34.027	18.720	3.12	-40.361	-27.693	-10.906	35	0.00

Hypothesis:

H_0: There is no significant difference between the pretest and posttest scores of metacognitive skills

H_1: There is a significant difference between the pretest and posttest scores of metacognitive skills

The test yields a significance value (Sig. 2-tailed) of 0.000, which is less than the alpha level $\alpha = 0.05$. Therefore, H_0 is rejected and H_1 is accepted. The results confirm a statistically significant difference between the pretest and posttest scores. The negative mean difference -34.028 explicitly indicates that the posttest scores are significantly higher than the pretest scores. Consequently, it is concluded that the POGIL based Student Worksheets are effective in improving students' metacognitive skills on chemical equilibrium material.

The planning indicator exhibited the most dramatic improvement, which can be directly traced to the structured forethought activities embedded in the Orientation and Exploration phases of the POGIL based worksheets. During the Orientation phase, students were confronted with authentic, industrially-relevant disequilibrating scenarios. This was not a mere introduction but a cognitive trigger designed to activate problem-sensing and goal-setting mechanisms. Students were compelled to articulate the core problem and formulate a specific investigatory goal.

This was followed by the Exploration phase, which functioned as a cognitive simulation chamber. Before touching any apparatus, students engaged in a dual-layered planning exercise documented in the LKPD:

a. Knowledge Inventory: Completing the "What I Know / What I Need to Know" column forced a metacognitive audit, making prior knowledge explicit and identifying precise conceptual gaps regarding equilibrium shifts.
b. Procedural Blueprinting: Designing the experimental procedure step by step, listing materials, and critically anticipating potential errors and mitigation strategies .

This process operationalized Flavell's metacognitive planning by transforming it from an implicit mental act into an explicit, documented procedure. The significant gain (0.82) suggests the LKPD successfully scaffolded students from reactive, ad hoc thinking to proactive, strategic investigation.

The moderate improvement in monitoring skills is intricately linked to the dialogic and evidentiary processes of the Concept Formation phase. Monitoring, the real-time awareness of comprehension and strategy efficacy, was engineered through two primary mechanisms in the LKPD:

a. The LKPD provided meticulously formatted observation tables. Students did not merely record results. They were required to juxtapose each empirical observation with their pre written prediction from the Exploration phase. Any mismatch a cognitive dissonance immediately flagged a need for monitoring. Prompting questions like, "Does the observed shift support or contradict your hypothesis based on Le Chatelier's principle?" forced an ongoing internal dialogue of verification.
b. The POGIL group structure, with mandated discussion, served as an externalized monitoring system. When a student asserted, "The color got darker, so the equilibrium shifted to the right," peers could challenge "But did you check if the temperature was constant? Could heat from your hands have affected it?" This peer to peer cross examination provided real-time, social feedback, a powerful form of other-regulated monitoring that, according to Vygotsky, precedes and cultivates self-regulation.

The N-Gain of 0.48, while moderate, reflects the inherent challenge of internalizing monitoring it requires splitting attention between doing the task and thinking about how one is doing the task. The LKPD provided the tools and social context to practice this demanding skill.

Evaluating, the retrospective analysis of outcomes and processes, was systematically trained in the Application and Reflection phases. The moderate gain (0.51) here reflects the development of higher-order, criteria-based judgment.

a. The LKPD's Application phase presented novel, multifaceted problems Success here required evaluative thinking beyond correctness. Students had to
   1) Evaluate Solution Efficacy: "Will increasing $[H^+]$ effectively precipitate $Cr(OH)_3$, and is it cost-effective?"
   2) Evaluate Consequences: "What is the environmental impact of the sludge produced?"
   3) Evaluate Ethical Fit: "Does this solution align with responsible waste management principles?" This multi-criteria evaluation mirrors real-world scientific practice.
b. The Reflection phase contained a dedicated column with a three-part prompt:
   1) Product Evaluation: "Did our group achieve the learning goal? What evidence supports this?"
   2) Process Evaluation: "Which strategies worked well? Which were inefficient"
   3) Personal Learning Evaluation: "What is one key misconception I corrected about dynamic equilibrium today?"

This structured protocol prevented superficial reflection and guided students to dissect the causal relationship between their strategies and their learning outcomes, a core aspect of metacognitive evaluation.

The statistically significant overall improvement ($p < 0.001$) is not a serendipitous outcome but the result of a theoretically coherent design. The POGIL-based LKPD functioned as an integrated metacognitive scaffold:

a. Constructivist Foundation: It created a "need to know," driving students to actively construct understanding, a process inherently monitored and regulated.
b. Vygotskyian Social Scaffolding: The group roles (Manager, Recorder, etc.) distributed metacognitive functions, allowing students to apprentice into skilled thinking through collaboration and dialogue.
c. Cognitive Load Management: By externalizing planning steps, providing data tables, and structuring reflection, the LKPD reduced extraneous cognitive load, freeing mental resources for the intrinsic cognitive and metacognitive work of understanding equilibrium (Vygotsky, 1978).

The finding that planning improved the most is pedagogically logical and encouraging. Planning is the foundational, preparatory skill. The LKPD's explicit focus here gave students a strong "launching pad." The moderate gains in monitoring and evaluating suggest these are more complex, iterative skills that likely require sustained practice beyond a single intervention. However, the establishment of a significant upward trajectory is crucial.

5. Comparison

This study aligns with previous research on POGIL-based LKPD, such as Sari & Azizah (2021) and Divamita & Azizah (2022), which also reported high validity, practicality, and effectiveness in improving metacognitive skills. However, this study extends previous work by focusing on chemical equilibrium a topic known for its abstractness and difficulty and by providing a detailed analysis of the alignment between POGIL phases and metacognitive indicators.

6. Conclusion

This study demonstrates that Process Oriented Guided Inquiry Learning (POGIL) based Student Worksheets are effective in significantly improving the metacognitive skills of eleventh grade students in the topic of Chemical Equilibrium. Quantitative analysis via the Paired Samples T-Test confirmed a statistically significant increase from pretest to posttest $p < 0.001$. A nuanced examination of the N-Gain scores revealed a high improvement in planning skills (0.82), indicating the worksheets' exceptional success in fostering strategic forethought. Moderate improvements were observed in monitoring (0.48) and evaluating (0.51) skills, reflecting meaningful development in students' ability to self-assess understanding in real-time and retrospectively judge their learning processes. These findings underscore that inquiry-based learning, when augmented with explicit, structured metacognitive scaffolding, can effectively cultivate the self regulatory capacities essential for mastering complex, abstract scientific concepts. For educators, this validates the investment in designing such materials. For researchers, it opens pathways to explore digital enhancements and longitudinal impacts of metacognitively rich pedagogies in science education.

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